Subject: Research Methodology and IPR

Subject Code: RMIK23507

Faculty Name: Mrs. Sushma K Sattigeri
Assistant Professor
Dept. of ECE

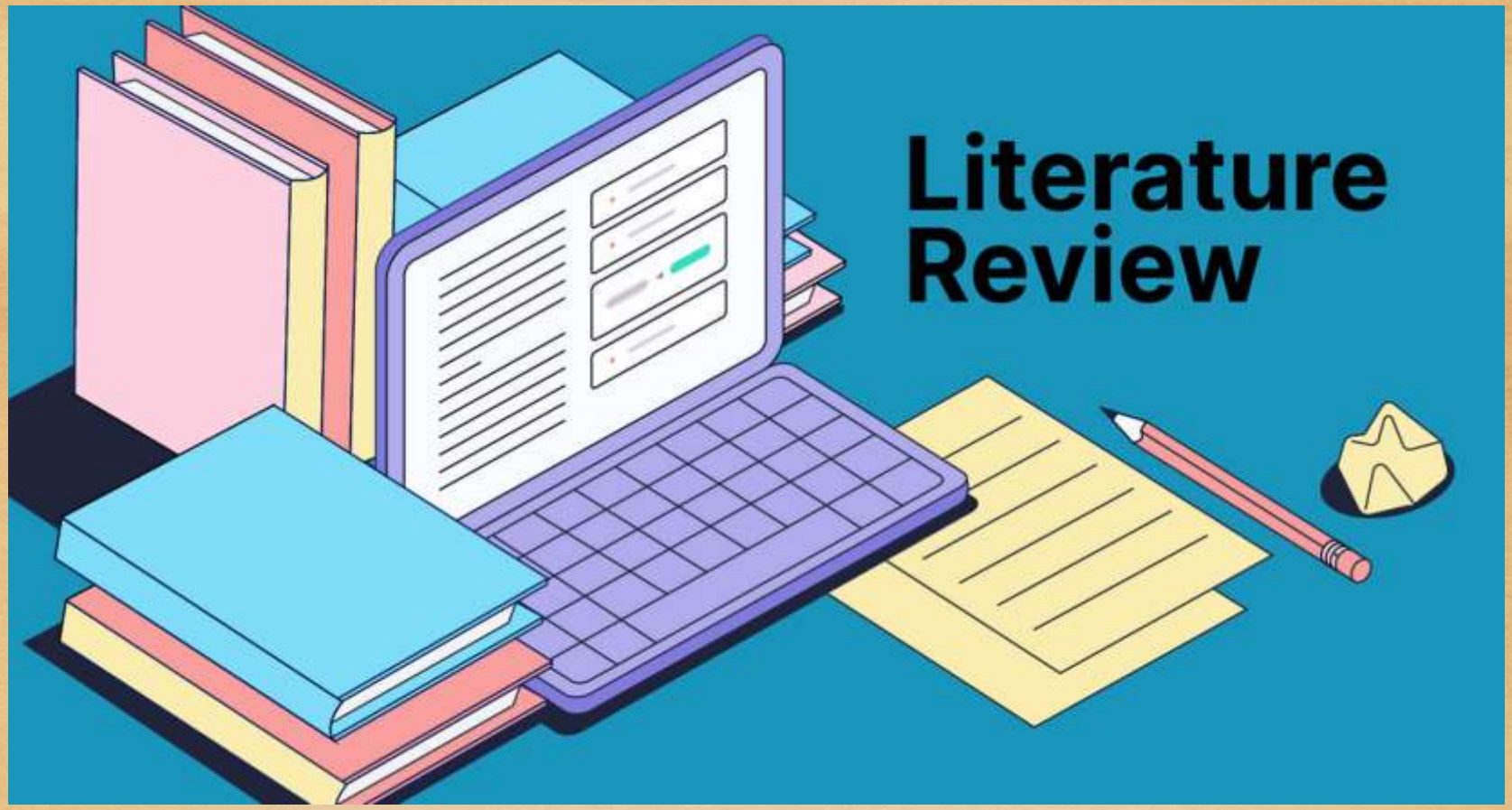
Module 2

Reviewing the Literature:

Place of the literature review in research, bringing clarity and focus to research problem, improving research methodology, broadening knowledge base in research area, enabling contextual findings, Review of the literature, searching the existing literature, reviewing the selected literature, developing a theoretical framework, developing a conceptual framework, writing about the literature reviewed.

Research Design:

Meaning of Research Design, Need for Research Design, Features of a Good Design, Important Concepts Relating to Research Design, Different Research Designs, Basic Principles of Experimental Designs, Important Experimental Designs.



Reviewing the Literature

The place of the literature review in research

- One of the **essential preliminary tasks** when you undertake a research study is to go through the existing literature in order to acquaint yourself with the **available body of knowledge in your area of interest.**
- Reviewing the literature can be **time consuming, daunting and frustrating**, but **it is also rewarding**.
- The **literature review** is an **integral part of the research process** and makes a valuable contribution to almost every operational step.
- It has value even before the first step; that is, when you are merely thinking about a research question that you may want to find answers through your research journey.
- In the initial stages of research it helps you to **establish the theoretical roots of your study**, **clarify your ideas** and **develop y**our research methodology.

The place of the literature review in research

- **Later in the process**, the literature review serves to **enhance and consolidate your own knowledge base** and helps you to integrate your findings with the existing body of knowledge.
- Since an important responsibility in research is to compare your findings with those of others, it is here that the literature review plays an extremely important role.
- During the write-up of your report it helps you to integrate your findings with existing knowledge – that is, to either **support or contradict earlier research**.
- The higher the academic level of your research, the more important a thorough integration of your findings with existing literature becomes.

The place of the literature review in research

In **summary**, a literature review has the following functions:

- It provides a **theoretical background** to your study.
- It helps you establish the links between what you are proposing to examine and what has already been studied.
- It enables you to show how your findings have contributed to the existing body of knowledge in your profession.
- It helps you to integrate your research findings into the existing body of knowledge.

The place of the literature review in research

In relation to your own study, the literature review can help in four ways. It can:

1. bring clarity and focus to your research problem;

2. improve your research methodology;

3. broaden your knowledge base in your research area; and

4. contextualise your findings.

1.Bringing clarity and focus to your research problem

- The literature review involves a **paradox**.
- On the one hand, you cannot effectively undertake a literature search **without some idea of the problem you wish to investigate.**
- On the other hand, the literature review can play an extremely important role in **shaping your research problem** because the process of reviewing the literature helps you to understand the subject area better and thus helps you to conceptualise your research problem clearly and precisely and makes it more relevant and pertinent to your field of enquiry.

Bringing clarity and focus to your research problem

- When reviewing the literature you learn **what aspects of your subject area have been examined by others**, what they have found out about these aspects, what **gaps** they have identified and what **suggestions they have made for further research.**
- All these will help you gain a greater insight into your own research questions and provide you with clarity and focus which are central to a relevant and valid study.
- In addition, it will help you to focus your study on areas where there are gaps in the existing body of knowledge, thereby enhancing its relevance.

2.Improving your research methodology

- Going through the literature acquaints you with the methodologies that have been used by others to find answers to research questions similar to the one you are investigating.
- A literature review tells you if others have used procedures and methods similar to the ones that you are proposing, which procedures and methods have worked well for them and what problems they have faced with them.
- By becoming **aware of any problems and pitfalls**, you will be **better** positioned to select a metho
  answers to your research que
- This will increase **your confidence in the methodology** you plan to use and will equip you to defend its

3.Broadening your knowledge base in your research area

Most important function of the literature review

read widely around the subject area

- It is important that you know what other researchers have found in regard to the same or similar questions, what theories have been put forward and what **gaps exist** in the relevant body of knowledge.
- When you undertake a research project for a higher degree **(e.g. an MA or a PhD)** you are expected to be an ***expert in your area of research***.
- A thorough literature review helps you to fulfil this expectation.
- Another important reason for doing a literature review is that it helps you to **understand how the findings of your study fit into the existing body of knowledge** (Martin 1985: 30).

4.Enabling you to contextualise your findings

- Obtaining answers to your research questions is comparatively easy: the **difficult part is examining how your findings fit into the existing body of knowledge.**
- How do answers to your research questions compare with what others have found?
- What contribution have you been able to make to the existing body of knowledge? How are your findings different from those of others?
- Undertaking a literature review will enable you to compare your findings with those of others and answer these questions.
- It is important to place your findings in the context of what is already known in your field of enquiry.

How to review the literature

- If you do not have a specific research problem, you should review the literature in **your broad area of interest** with the aim of gradually narrowing it down to what you want to find out about.
- After that the literature review should be focused around your research problem.
- There is a danger in reviewing the literature without having a reasonably specific idea of what you want to study.
- It can ***condition your thinking*** about your *study and the methodology* you might use, resulting in a less innovative choice of research problem and methodology than otherwise would have been the case.
- Hence, you should try **broadly to conceptualise your research problem** before undertaking your major literature review.

How to review the literature

There are four steps involved in conducting a literature review:

1. Searching for the existing literature in your area of study.
2. Reviewing the selected literature.
3. Developing a theoretical framework.
4. Developing a conceptual framework.

The skills required for these tasks are different. Developing theoretical and conceptual frameworks is more difficult than the other tasks.

1.Searching for the existing literature

- To search effectively for the literature in your field of enquiry, it is imperative that you have **at least some idea of the broad subject area** and **of the problem** you wish to investigate, in order to set parameters for your search.
- Next, **compile a bibliography** for this broad area.
- There are three sources that you can use to prepare a bibliography:
  - **books;**
  - **journals;**
  - **the Internet.**

i.Books

Though books are a central part of any bibliography, they have their disadvantages as well as advantages.

- The **main advantage** is that the material published in books is usually **important** and of **good quality**, and the findings are '**integrated with other research** to form a coherent body of knowledge' (Martin 1985: 33).

- The **main disadvantage** is that the material is **not completely up to date**, as it can take a few years between the completion of a work and its publication in the form of a book.

- The **best way to search for a book** is to look at your ***library catalogues.***

- When librarians catalogue a book they also assign to it subject headings that are usually based on ***Library of Congress Subject Headings*.**

- If you are not sure, ***ask your librarian*** to help you find the best subject heading for your area. This can save you a lot of time.

Books

- Publications such as ***Book Review Index*** can help you to locate books of interest.
- Use the **subject catalogue or keywords** option to search for books in your area of interest.
- ***Narrow the subject area*** searched by selecting the appropriate keywords.
- Look through **these titles carefully** and identify the books you think are *likely to be of interest* to you.

Books

- If you think the titles seem appropriate to your topic, ***print them*** out (if this facility is available), as this will save you time, or note them down on a piece of paper.
- Be aware that sometimes a ***title*** does not provide **enough information to help you decide if a book** is going to be of use so you may have to examine its contents too.
- When you have ***selected 10–15 books*** that you think are appropriate for your topic, *examine the bibliography* of each one.
- It will *save time if you photocopy their bibliographies*.

Books

- Go through these bibliographies carefully ***to identify the books common to several*** of them.
- If a book has been referenced by a number of authors, you should include it in your reading list.
- Prepare a final list of books that you consider essential reading.
- Having prepared your reading list, locate these books in your library or borrow them from other sources.
- **Examine their contents to double-check** that they really are relevant to your topic.

Books

- If you find that a **book is not relevant** to your research, delete it from your reading list.
- If you find that something in a book's contents is relevant to your topic, make an **annotated bibliography.**
- An **annotated bibliography** contains a brief abstract of the aspects covered in a book and your own notes of its relevance.
- Be careful to keep track of your references.
- To do this you can prepare your **own card index** or use a computer program such as Endnotes or Pro-Cite.

ii.Journals

- If you have been able to identify any **useful journals and articles**, **prepare a list** of those you want to examine, by journal.
- **Select one** of these journals and, starting with the **latest issue**, examine its contents page to see if there is an article of relevance to your research topic.
- If you feel that a particular article is of interest to you**, read its abstract.**
- If you think you are likely to use it, depending upon your financial resources, either **photocopy it, or prepare a summary** and record its reference for later use.
- There are **several sources** designed to make your search for journals easier and these can save your enormous time.

- They are: indices of journals (e.g. *Humanities Index*); abstracts of articles (e.g. *ERIC*); citation indices (e.g. *Social Sciences Citation Index*).

- Each of these indexing, abstracting and citation services is available in print, or accessible through the Internet.

- In most libraries, information on books, journals and abstracts is stored on computers.

- In each case the information is classified by subject, author and title.

- You may also have the keywords option (author/keyword;title/keyword; subject/keyword; expert/keyword; or just keywords).
- What system you use depends upon what is available in your library and what you are familiar with.
- There are specially prepared electronic databases in a number of disciplines.
- These can also be helpful in preparing a bibliography.
- For example, most libraries carry the electronic databases

Journals

- Select the database most appropriate to your area of study to see if there are any useful references.

- Of course, any computer database search is restricted to those journals and articles that are already on the database.

- You should also talk to your research supervisor and other available experts to find out about any additional relevant literature to include in your reading list.

iii.The Internet

- In almost every academic discipline and professional field, the Internet has become an important tool for finding published literature.

- Through an Internet search you can identify published material in books, journals and other sources with immense ease and speed.

- An Internet search is carried out through search engines, of which there are many, though the most commonly used are *Google* and *Yahoo*.

- Searching through the Internet is very similar to the search for books and articles in a library using an electronic catalogue, as it is based on the use of keywords.

- An Internet search basically identifies all material in the database of a search engine that contains the keywords you specify, either individually or in combination.

- It is important that you choose words or combinations of words that other people are likely to use.

- According to Gilbert (2008: 73), 'Most search facilities use Boolean logic, which allows three types of basic search "AND", "OR" and "NOT".'

- With practice you will become more efficient and effective in using keywords in combination with AND, OR and NOT, and so learn to narrow your search to help you identify the most relevant references.

2.Reviewing the selected literature

- Now that you have identified several books and articles as useful, the next step is to start reading them critically.

- To pull together themes and issues that are of relevance to your study.

- Unless you have a theoretical framework of themes in mind to start with, use separate sheets of paper for each theme or issue you identify as you go through selected books and articles

The following example details the process.

- The author recently examined, as part of an evaluation study, the extent of practice of the concept of 'community responsiveness' in the delivery of health services in Western Australia by health service providers.

- Before evaluating the extent of its use, pertinent literature relating to 'community responsiveness in health' was identified and reviewed.

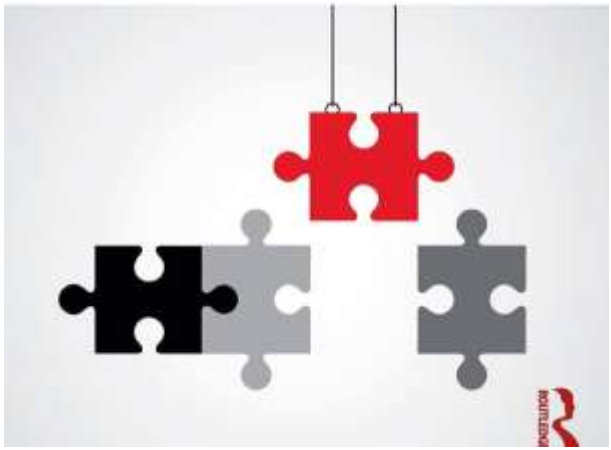
- Through this review, many themes emerged, which became the basis of developing the theoretical framework for the study.

Out of all of this, the following themes were selected to construct the theoretical framework for the evaluation study

- Community responsiveness: what does it mean?
- Philosophies underpinning community responsiveness.
- Historical development of the concept in Australia.
- The extent of use in health planning?
- Strategies developed to achieve community responsiveness.
- Indicators of success or failure.
- Seeking community participation.
- Difficulties in implementing community responsiveness.
- Attitude of stakeholders towards the concept of community responsiveness.

3. Developing a theoretical framework

- Examining the literature can be a never-ending task, but as you have limited time it is **important to set parameters** by reviewing the literature in relation to some main themes pertinent to your research topic.



- As you start reading the literature, you will soon discover that the problem you wish to investigate has its **roots in a number of theories** that have been developed from different perspectives.
- The **information** obtained from different books and journals now needs to be sorted under the main themes and theories, highlighting agreements and disagreements among the authors and **identifying the unanswered questions or gaps**.

Developing a theoretical framework

- You will also realise that the literature deals with a number of aspects that have a direct or indirect bearing on your research topic.

- Use these aspects as a basis for developing your theoretical framework.

- Your review of the literature should sort out the information, as mentioned earlier, within this framework.

- Unless you review the literature in relation to this framework, you will not be able to develop a focus in your literature search: that is, *your theoretical framework provides you with a guide as you read.*

Developing a theoretical framework

- This brings us to the **paradox** mentioned previously: until you go through the literature you cannot develop a theoretical framework, and until you have developed a theoretical framework you cannot effectively review the literature.
- The solution is to read some of the literature and then attempt to develop a framework, even a loose one, within which you can organise the rest of the literature you read.
- As you read more about the area, you are **likely to change the framework**.
- However, without it, you will get **bogged down in a great deal of unnecessary reading** and note-taking that may not be relevant to your study.

Developing a theoretical framework

Literature pertinent to your study may deal with two types of information:

1. universal;

2. more specific (i.e. local trends or a specific programme).

In writing about such information you should start with the general information, gradually narrowing it down to the specific.

Look at the example in Figure 3.1a and 3.1b

Developing a theoretical framework

If you want to study the relationship between mortality and fertility, you should **review the literature about:**

- *Fertility* – trends, theories, some of the indices and critiques of them, factors affecting fertility, methods of controlling fertility, factors affecting acceptance of contraceptives, and so on;
- *Mortality* – factors affecting mortality, mortality indices and their sensitivity in measuring change in mortality levels of a population, trends in mortality, and so on; and most importantly,
- *The relationship between fertility and mortality* – theories that have been put forward to explain the relationship, implications of the relationship.

FIGURE 3.1a ***Developing a theoretical framework – the relationship between mortality and fertility***

Developing a theoretical framework

Develop theoretical framework:

- It should revolve around theories – put forward about the relationship between mortality and fertility.
- You will discover that a number of theories have been proposed to explain this relationship.

For example

- It has been explained from economics, religious, medical and psychological perspectives.
- Within each perspective several theories have been put forward: 'insurance theory', 'fear of non-survival', 'replacement theory', 'price theory', 'utility theory', 'extra' or 'hoarding theory' and 'risk theory'.

FIGURE 3.1a *Developing a theoretical framework – the relationship between mortality and fertility*

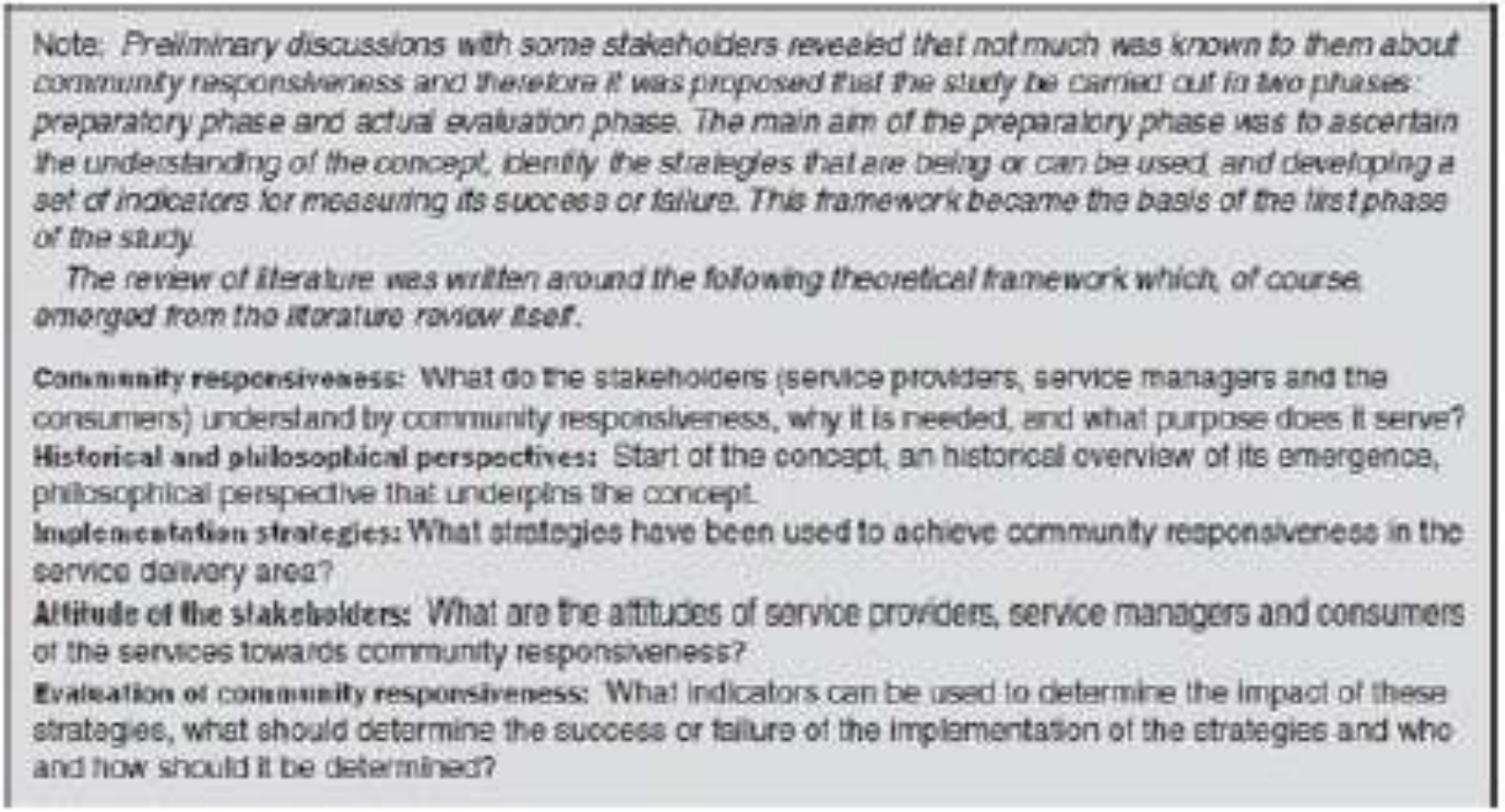
Developing a theoretical framework

Your literature review should be written under the following headings, (most of them involving examination of the relationships between fertility and mortality:

- Fertility theories;
- The theory of demographic transition;
- Trends in fertility (global, and then narrow it to national and local levels):
- Methods of contraception (their acceptance and effectiveness);
- Factors affecting mortality;
- Trends in mortality (and their implications);
- Measurement of mortality indices (their sensitivity)
- Relationships between fertility and mortality (different theories such as ‘insurance’, ‘fear of non-survival’, ‘replacement’, ‘price’, ‘utility’, ‘risk’, and ‘hoarding’).

FIGURE 3.1a *Developing a theoretical framework – the relationship between mortality and fertility*

Developing a theoretical framework



Note: *Preliminary discussions with some stakeholders revealed that not much was known to them about community responsiveness and therefore it was proposed that the study be carried out in two phases: preparatory phase and actual evaluation phase. The main aim of the preparatory phase was to ascertain the understanding of the concept, identify the strategies that are being or can be used, and developing a set of indicators for measuring its success or failure. This framework became the basis of the first phase of the study.*

The review of literature was written around the following theoretical framework which, of course, emerged from the literature review itself.

Community responsiveness: What do the stakeholders (service providers, service managers and the consumers) understand by community responsiveness, why it is needed, and what purpose does it serve?
Historical and philosophical perspectives: Start of the concept, an historical overview of its emergence, philosophical perspective that underpins the concept.
Implementation strategies: What strategies have been used to achieve community responsiveness in the service delivery area?
Attitude of the stakeholders: What are the attitudes of service providers, service managers and consumers of the services towards community responsiveness?
Evaluation of community responsiveness: What indicators can be used to determine the impact of these strategies, what should determine the success or failure of the implementation of the strategies and who and how should it be determined?

FIGURE 3.1b ***Theoretical framework for the study 'community responsiveness in health'***

Developing a conceptual framework

- The conceptual framework is the *basis of your research problem*.
- It stems from the theoretical framework and usually focuses on the section(s) which become the basis of your study.
- Whereas the theoretical framework consists of the theories or issues in which your study is embedded, the conceptual framework describes the aspects you selected from the theoretical framework to become the basis of your enquiry.

- For instance, in the *example cited in Figure 3.1a*, the theoretical framework includes **all the theories** that have been put forward to explain the ***relationship between fertility and mortality.***
- However, out of these, you may be **planning to test only one**, say the fear of non-survival. .
- Hence the **conceptual framework grows out of the theoretical framework** and **relates to the specific research problem**.

Writing about the literature reviewed

Writing about the literature reviewed

- Now, all that **remains to be done is to write** about the literature you have reviewed.
- As mentioned in the beginning of this chapter, *two of the broad functions of a literature review are*

  (1) to provide a theoretical background to your study and

  (2) to enable you to contextualise your findings in relation to the existing body of knowledge in addition to refining your methodology.
- The *content of your literature review should reflect these two purposes*.

Writing about the literature reviewed

- In order to **fulfil the first purpose**, you should ***identify and describe various theories*** relevant to your field; and ***specify gaps*** in existing knowledge in the area, recent advances in the area of study, current trends and so on.
- In order to ***comply with the second function*** you should ***integrate the results from your study*** with specific and relevant ***findings from the existing literature*** by comparing the two for confirmation or contradiction.
- Note that at this stage you can only accomplish the first function of the literature review, to provide a theoretical background to your study.
- For the **second function**, the contextualisation of the findings, you have to *wait till you are at the research report writing stage*.

Writing about the literature reviewed

- ✓ While reading the literature for theoretical background of your study, you will realise that certain themes have emerged.
- ✓ List the main ones, converting them into subheadings.
- ✓ Some people write up the entire literature review in one section, entitled '**Review of the literature**', '**Summary of literature**' or '**The literature review**', without subheadings, but the author strongly suggests that you write your literature review under subheadings based upon the main themes that you have discovered and which form the basis of your theoretical framework.
- ✓ These subheadings should be **precise, descriptive of the theme in question** and follow a **logical progression**.
- ✓ Now, under each subheading, **record the main findings** with respect to the theme in question (thematic writing), highlighting the reasons for and against an argument if they exist, and **identifying gaps and issues**.
- ✓ Figure 3.2 shows the subheadings used to describe the themes in a literature review conducted by the author for a study entitled '**Intercountry adoption in Western Australia**'.

Writing about the literature reviewed

Intercountry adoption in Western Australia

(A profile of adoptive families)

The literature was reviewed under the following themes:

- Introduction (*introductory remarks about adoption*)
- History and philosophy of adoption
- Reasons for adoption
- Trends in adoption (*global and national*)
- Intercountry adoption
- History of intercountry adoption in Western Australia
- Trends in intercountry adoption in Western Australia
- The Adoption Act in Western Australia
- The adoption process in Western Australia
- Problems and issues in adoption
- Gaps in the literature (*in this case it was a lack of information about those parents who had adopted children from other countries that became the basis of the study*)

FIGURE 3.2 Sample of outline of a literature review

Writing about the literature reviewed

- The second broad function of the literature review – contextualising the findings of your study – *requires you to compare very systematically your findings with those made by others*.

- Quote from these studies to show how your findings contradict, confirm or add to them.

- It places *your findings in the context of what others have found out* providing complete reference in an acceptable format.

- This function is undertaken, as mentioned earlier, when writing about your findings, that is after analysis of your data.

Module-2 Research Design

Meaning of Research Design

The most important step after defining the research problem is preparing the design of the research project, which is popularly known as the research design.

Meaning of Research Design

- "A research design is the **arrangement of conditions for collection and analysis of data** in a manner that aims to combine relevance to the research purpose with economy in procedure."
- In fact, the research design is the **conceptual structure within which research is conducted**; it constitutes the blueprint for the collection, measurement and analysis of data.
- As such the design includes an outline of what the researcher will do from writing the hypothesis and its operational implications to the final analysis of data.

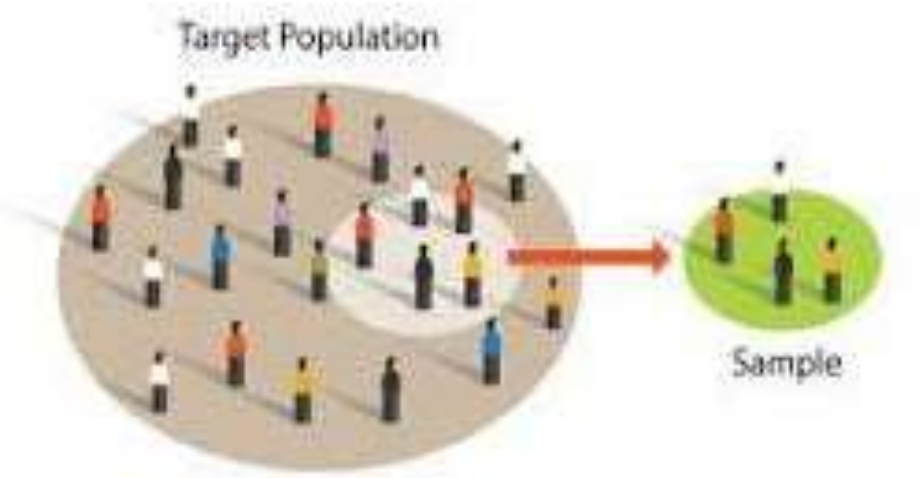
The research design highlights decisions which include:

1. The nature of the study
2. The purpose of the study
3. The location where the study would be conducted
4. The nature of data required
5. From where the required data can be collected
6. What time period the study would cover
7. The type of sample design that would be used
8. The techniques of data collection that would be used
9. The methods of data analysis that would be adopted and
10. The manner in which the report would be prepared

In view of the stated research design decisions, the overall research design may be divided into the following parts:

a) **The sampling design** that deals with the method of selecting items to be observed for the selected study

b) **The observational design** that relates to the conditions under which the observations are to be made



c) **The statistical design** that concerns with the question of how many items are to be observed, and how the information and data gathered are to be analyzed and

d) **The operational design** that deals with the techniques by which the procedures specified in the sampling, statistical and observational designs can be carried out

Statistical Design

Operational Design

NEED FOR RESEARCH DESIGN

- Research design is needed because it facilitates the smooth sailing of the various research operations, thereby making research as efficient as possible yielding maximal information with minimal expenditure of effort, time and money.

- Just as for better, economical and attractive construction of a house, we need a blueprint (or what is commonly called the map of the house) well thought out and prepared by an expert architect, similarly we need a research design or a plan in advance of data collection and analysis for our research project.

- Research design stands for advance planning of the methods to be adopted for collecting the relevant data and the techniques to be used in their analysis, keeping in view the objective of the research and the availability of staff, time and money.

NEED FOR RESEARCH DESIGN

- Preparation of the research design should be done with great care as any error in it may upset the entire project.
- Research design, in fact, has a great bearing on the reliability of the results arrived at and as such constitutes the firm foundation of the entire edifice of the research work.
- The design helps the researcher to organize his ideas in a form whereby it will be possible for him to look for flaws and inadequacies.
- Such a design can even be given to others for their comments and critical evaluation.
- In the absence of such a course of action, it will be difficult for the critic to provide a comprehensive review of the proposed study.

Features of a Good Design:

A good design is often characterised by adjectives like flexible, appropriate, efficient, economical and so on.

Generally, the design which minimises bias and maximises the reliability of the data collected and analysed is considered a good design.

A research design appropriate for a particular research problem, usually involves the consideration of the following factors:

(i) the means of obtaining information;
(ii) the availability and skills of the researcher and his staff, if any;
(iii) the objective of the problem to be studied;
(iv) the nature of the problem to be studied; and
(v) the availability of time and money for the research work.

Features of a Good Design:

- we can state the important features of a research design as under:
- (i) It is a plan that specifies the sources and types of information relevant to the research problem.
- (ii) It is a strategy specifying which approach will be used for gathering and analysing the data.
- (iii) It also includes the time and cost budgets since most studies are done under these two constraints.
- In brief, research design must, at least, contain—(a) a clear statement of the research problem; (b) procedures and techniques to be used for gathering information; (c) the population to be studied; and (d) methods to be used in processing and analysing data.

Features of a Good Design:

- If the research study happens to be an exploratory or a formulative one, wherein the major emphasis is on discovery of ideas and insights, the research design most appropriate must be flexible enough to permit the consideration of many different aspects of a phenomenon.

- But when the purpose of a study is accurate description of a situation or of an association between variables (or in what are called the descriptive studies), accuracy becomes a major consideration and a research design which minimises bias and maximises the reliability of the evidence collected is considered a good design.

- Studies involving the testing of a hypothesis of a causal relationship between variables require a design which will permit inferences about causality in addition to the minimization of bias and maximization of reliability.

Important Concepts Relating to Research Design

Important Concepts Relating to Research Design

1.Dependent and independent variables:

- A magnitude that varies is known as a variable.
- The concept may assume different quantitative values like height, weight, income etc.
- Qualitative variables are not quantifiable in the strictest sense of the term.
- However, the qualitative phenomena may also be quantified in terms of the presence or absence of the attribute(s) considered
- In statistical terms, they are also known as discrete variables.

Important Concepts Relating to Research Design

1.Dependent and independent variables:

- **For example, age is a continuous variable**, whereas the number of children is a non-continuous variable.

- When changes in one variable depend upon the changes in other variable or variables, it is known as a dependent or endogenous variable, and the variables that cause the changes in the dependent variable are known as the independent or explanatory or exogenous variables.

Important Concepts Relating to Research Design

2.Extraneous variables:

The independent variables which are not directly related to the purpose of the study but affect the dependent variables, are known as extraneous variables.

- For instance, assume that a researcher wants to test the hypothesis that there is a ***relationship between children's school performance and their self-confidence,*** in which case the latter is an independent variable and the former, a dependent variable.
- In this context, intelligence may also influence the school performance.
- However, since it is not directly related to the purpose of the study undertaken by the researcher, it would be known as an extraneous variable

Important Concepts Relating to Research Design

3. **Control:**

- One important characteristic of a good research design is to minimise the influence or effect of extraneous variable(s).
- The technical term 'control' is used when we design the study minimising the effects of extraneous independent variables.
- In experimental researches, the term 'control' is used to refer to restrain experimental conditions.

Important Concepts Relating to Research Design

4. **Confounded relationship:**

- The relationship between the dependent and independent variables is said to be confounded by an extraneous variable, when the dependent variable is not free from its effects.

5.**Research hypothesis:**

- When a prediction or a hypothesized relationship is tested by adopting scientific methods, it is known as **research hypothesis.**
- The research hypothesis is a predictive statement which relates to a dependent variable and an independent variable.
- Generally, a research hypothesis must consist of at least one dependent variable and one independent variable.
- Whereas, the relationships that are assumed but not to be tested are predictive statements that are not to be objectively verified, thus are not classified as research hypotheses

Important Concepts Relating to Research Design

6. **Experimental and non-experimental hypothesis testing research**:

- When the objective of a research is to test a research hypothesis, it is known as ***hypothesis testing research***.
- Such research may be in the nature of experimental design or nonexperimental design.
- The research in which the independent variable is manipulated is known as ***experimental hypothesis-testing research***', whereas the research in which the independent variable is not manipulated is termed as ***'non-experimental hypothesis- testing research***'.

7. **Experimental and control groups:**

- When a group is exposed to usual conditions in an experimental hypothesis-testing research, it is known as '***control group***'.
- On the other hand, when the group is exposed to certain new or special condition, it is known as an '***experimental group***'.

Important Concepts Relating to Research Design

8. Treatments:

Treatments refer to the different conditions to which the experimental and control groups are subject to.

9. Experiment:

- Experiment refers to the process of verifying the truth of a statistical hypothesis relating to a given research problem.
- For instance, an experiment may be conducted to examine the yield of a certain new variety of rice crop developed.
- Further, Experiments may be categorized into two types, namely, **'absolute experiment' and 'comparative experiment".**
- *If a researcher wishes to determine the impact of a chemical fertilizer on the yield of a particular variety of rice crop, then it is known* ***as absolute experiment****.*
- *Meanwhile, if the researcher wishes to determine the impact of chemical fertilizer as compared to the impact of bio-fertilizer, then the experiment is known as a* ***comparative experiment****.*

Important Concepts Relating to Research Design

10. Experimental unit(s):

Experimental units refer to the pre-determined plots, characteristics or the blocks, to which different treatments are applied.

Different Research Designs

Types of research design: There are different types of research designs.

(1) Exploratory research design

(2) Descriptive and diagnostic research design

(3) Hypothesis-testing research design

Different Research Designs:

1. Exploratory research design:

- The Exploratory Research Design is known as formulative research design.

- The main objective of using such a research design is to formulate a research problem for an in-depth or more precise investigation, or for developing a working hypothesis from an operational aspect.

- The major purpose of such studies is the discovery of ideas and insights.

- Therefore, such a research design suitable for such a study should be flexible enough to provide opportunity for considering different dimensions of the problem understudy.

Different Research Designs:

2. Descriptive and diagnostic research design:

- A ***Descriptive Research Design*** is concerned with describing the characteristics of a particular individual or a group.
- Meanwhile, a ***diagnostic research design*** determines the frequency with which a variable occurs or its relationship with another variable.
- In other words, *the study analyzing whether a certain variable is associated with another comprises a diagnostic* research study.
- On the other hand, a study that is concerned with specific predictions or with the narration of facts and characteristics related to an individual, group or situation, are instances of descriptive research studies

Different Research Designs

Research Design	*Type of study*	
	Exploratory of Formulative	*Descriptive/Diagnostic*
Overall design	Flexible design (design must provide opportunity for considering different aspects of the problem)	Rigid design (design must make enough provision for protection against bias and must maximise reliability)
(i) Sampling design	Non-probability sampling design (purposive or judgement sampling)	Probability sampling design (random sampling)
(ii) Statistical design	No pre-planned design for analysis	Pre-planned design for analysis
(iii) Observational design	Unstructured instruments for collection of data	Structured or well thought out instruments for collection of data
(iv) Operational design	No fixed decisions about the operational procedures	Advanced decisions about operational procedures.

Different Research Designs:

3. Hypothesis-Testing research design:

- Hypothesis-Testing Research Designs are those in which the *researcher tests the hypothesis of causal relationship between two or more variables.*

- These studies require procedures that would not only decrease bias and enhance reliability, *but also facilitate deriving inferences about the causality*. Generally, experiments satisfy such requirements.

- Hence, when research design is discussed in such studies, it often refers to the design of experiments.

Basic Principles of Experimental Designs

Professor Fisher has enumerated three principles of experimental designs:

(1) The Principle of Replication-

- **the experiment** should be repeated more than once.
- Thus, each treatment is applied in many experimental units instead of one.
- By doing so the statistical accuracy of the experiments is increased.

(2) The Principle of Randomization-

- The Principle of Randomization **provides protection,** when we conduct an experiment, against the effect of extraneous factors by randomization.
- In other words, this principle indicates that we should design or plan the experiment in such a way that the variations caused by extraneous factors can all be **combined** under the general heading of **"chance**."

Basic Principles of Experimental Designs

(3)Principle of Local Control-

- the extraneous factor, the known source of variability, is made to vary deliberately over as wide a range as necessary and this needs to be done in such a way that the variability it causes can be measured and hence eliminated from the experimental error.
- This means that we should plan the experiment in a manner that we can perform a **two-way analysis of variance,** in which the **total variability of the data is divided into three components** attributed to, the extraneous factor and experimental error.
- In other words, according to the principle of local control, we first divide the field into several homogeneous parts, known as blocks, and then each such block is divided into parts equal to the number of treatments. Then the treatments are randomly assigned to these parts of a block. Dividing the field into several homogenous parts is known as **'blocking'.**

Important Experimental Designs

Experimental design refers to the **framework or structure of an experiment** and as such there are several experimental designs.

Informal experimental designs - use a less sophisticated form of analysis based on differences in magnitudes

Formal experimental designs offer relatively *more control and use precise statistical procedures* for analysis.

Important experiment designs are as follows:

(*a*) Informal experimental designs:

(i) Before-and-after without control design.

(ii) After-only with control design.

(iii) Before-and-after with control design.

(*b*) Formal experimental designs:

(i) Completely randomized design (C.R. Design).

(ii) Randomized block design (R.B. Design).

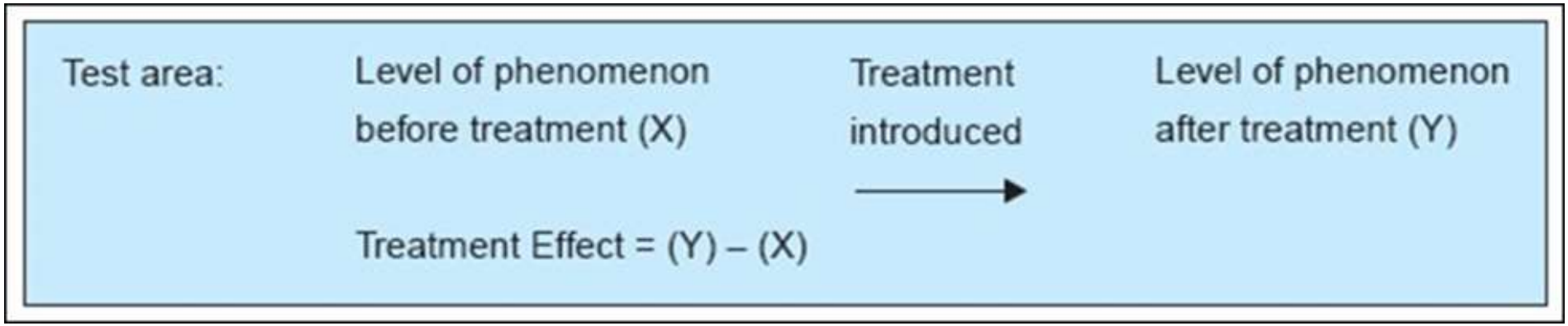
(iii) Latin square design (L.S. Design).

(iv) Factorial designs.

Important Experimental Designs

1. Before-and-after without control design-

- A single test group or area is selected and the dependent variable is measured before the introduction of the treatment. The treatment is then introduced and then the dependent variable is measured again.
- The effect of the treatment would be equal to the level of the phenomenon after the treatment minus the level of the phenomenon before the treatment.
- The main difficulty of such a design is that with the passage of time considerable extraneous variations may be there in its treatment effect.


Test area:
Level of phenomenon before treatment (X)
Treatment introduced
Level of phenomenon after treatment (Y)
Treatment Effect = (Y) – (X)

Important Experimental Designs

2. After-only with control design-

Two groups or areas (test area and control area) are selected and the treatment is introduced into the test area only.

The dependent variable is then measured in both the areas at the same time.

Treatment impact is assessed by subtracting the value of the dependent variable in the control area from its value in the test area.

The **basic assumption** in such a design is that **the two areas are identical** with respect to their behaviour towards the phenomenon considered.

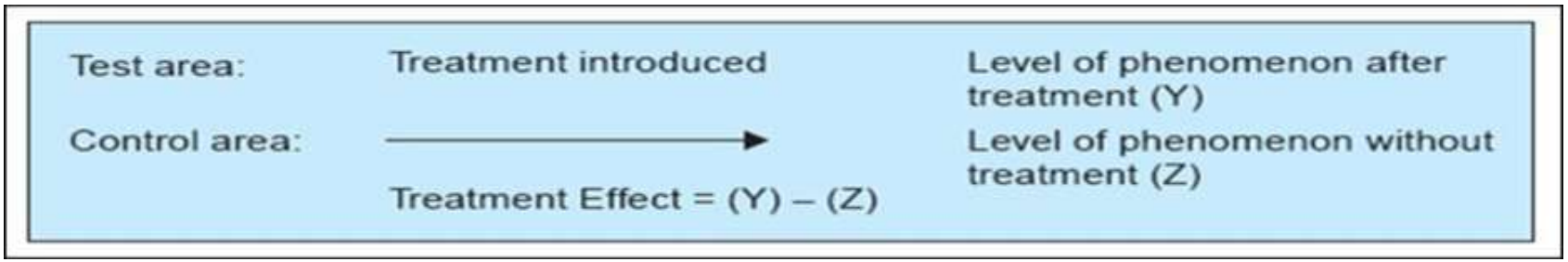
If this assumption is not true, there is the possibility of extraneous variation entering into the treatment effect.

However, data can be collected in such a design without the introduction of problems with the passage of time.

In this respect the design is **superior to before-and-after without control design**.

Important Experimental Designs

2. After-only with control design-

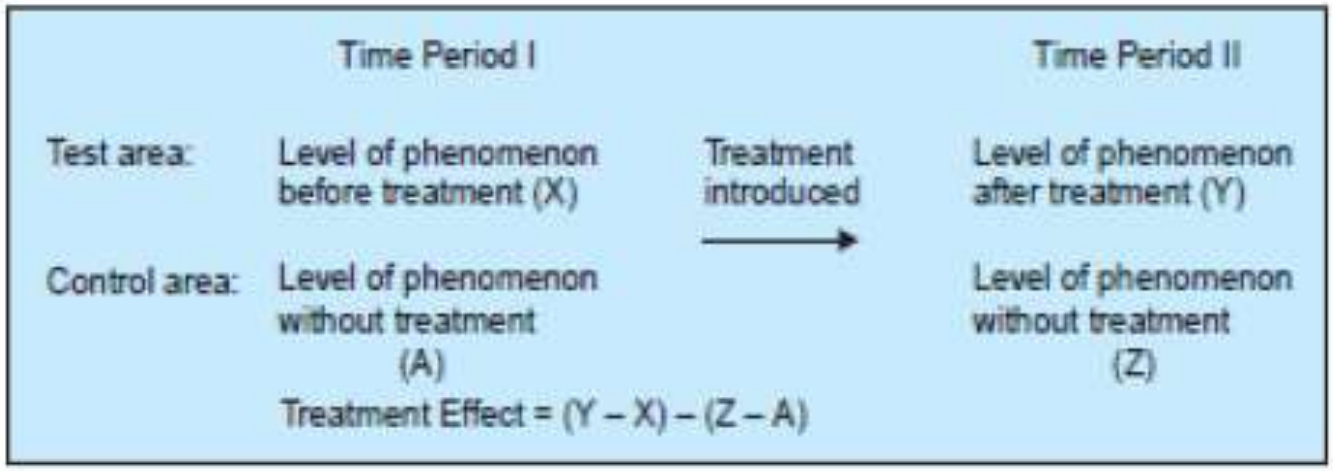

Test area:
Treatment introduced
Level of phenomenon after treatment (Y)
Control area:
Level of phenomenon without treatment (Z)
Treatment Effect = (Y) – (Z)

Important Experimental Designs

3. Before-and-After with Control Design:

- In this design two areas are selected and the dependent variable is measured in both the areas for an identical time-period before the treatment.
- The treatment is then introduced into the test area only, and the dependent variable is measured in both for an identical time-period after the introduction of the treatment.
- The treatment effect is determined by subtracting the change in the dependent variable in the control area from the change in the dependent variable in test area.

This design can be shown in this way:


Time Period I
Time Period II
Test area:
Level of phenomenon before treatment (X)
Treatment introduced
Level of phenomenon after treatment (Y)
Control area:
Level of phenomenon without treatment (A)
Level of phenomenon without treatment (Z)
Treatment Effect = (Y – X) – (Z – A)

Important Experimental Designs

4. Completely randomized design (C.R. design)

- Involves only two principles viz., the principle of replication and the principle of randomization of experimental designs.
- It is the ***simplest possible design*** and its procedure of analysis is also easier.
- The essential characteristic of the design is that subjects are randomly assigned to experimental treatments (or vice-versa).
- For instance, if we have 10 subjects and if we wish to test 5 under treatment A and 5 under treatment B, the randomization process gives every possible group of 5 subjects selected from a set of 10 an equal opportunity of being assigned to treatment A and treatment B.
- Technically, when all the variations due to uncontrolled extraneous factors are included under the heading of chance variation, we refer to the design of experiment as C.R. design.

Important Experimental Designs

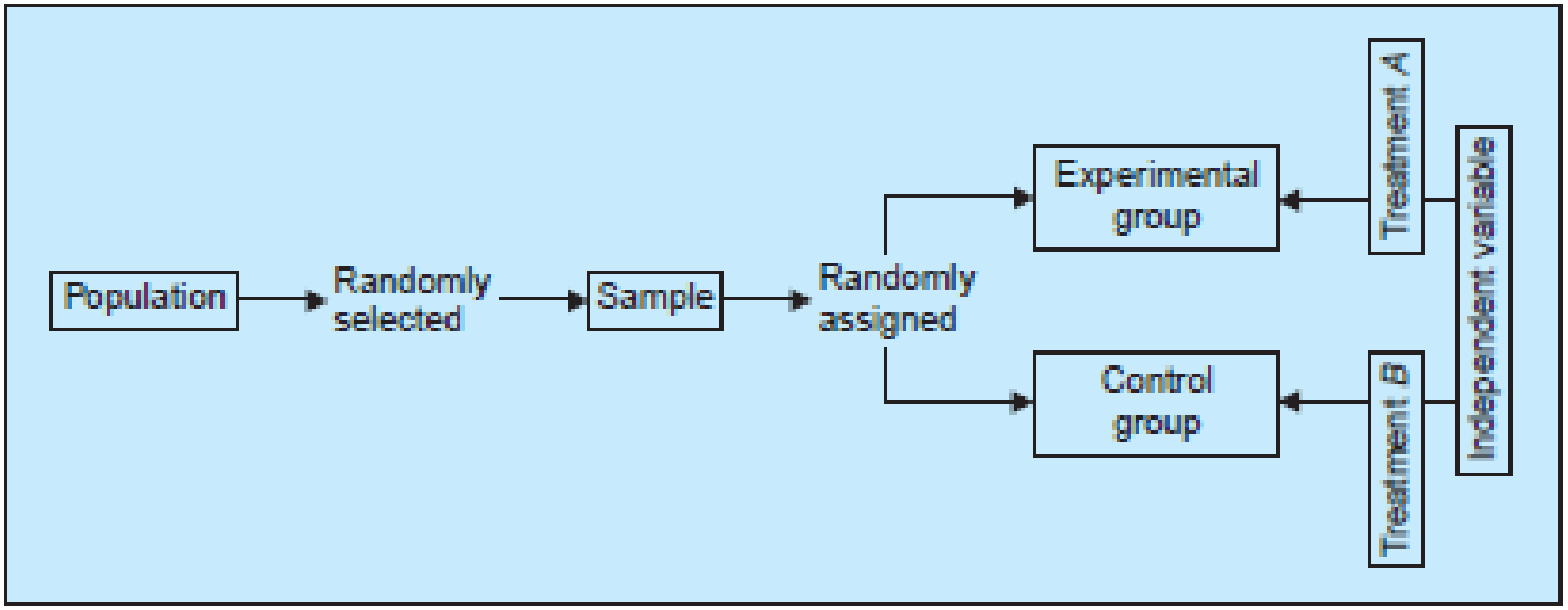
4. Completely randomized design (C.R. design):

(i) Two-group simple randomized design:

- In a two-group simple randomized design, first of all the population is defined and then from the population a sample is selected randomly.
- Further, requirement of this design is that items, after being selected randomly from the population, be randomly assigned to the experimental and control groups
- (Such random assignment of items to two groups is technically described as principle of randomization).
- Thus, this design yields two groups as representatives of the population.

Important Experimental Designs

In a diagram form this design can be shown in this way:



Important Experimental Designs

- Since in the sample randomized design the elements constituting the sample are randomly drawn from the same population and randomly assigned to the experimental and control groups, it becomes possible to draw conclusions on the basis of samples applicable for the population.
- The two groups (experimental and control groups) of such a design are given different treatments of the independent variable.
- This design of experiment is quite common in research studies concerning behavioural sciences.
- The merit of such a design is that it is simple and randomizes the differences among the sample items.
- But the limitation of it is that the individual differences among those conducting the treatments are not eliminated, i.e., it does not control the extraneous variable and as such the result of the experiment may not depict a correct picture.

Important Experimental Designs

- This can be illustrated by taking an example. Suppose the researcher wants to compare two groups of students who have been randomly selected and randomly assigned.
- Two different treatments viz., the usual training and the specialised training are being given to the two groups.
- The researcher hypothesises greater gains for the group receiving specialised training.
- To determine this, he tests each group before and after the training, and then compares the amount of gain for the two groups to accept or reject his hypothesis.
- This is an illustration of the two-groups randomized design, wherein individual differences among students are being randomized.
- But this does not control the differential effects of the extraneous independent variables (in this case, the individual differences among those conducting the training programme).

Important Experimental Designs

(ii) Random replications design:

- The limitation of the two-group randomized design is usually eliminated within the random replications design.
- In the illustration just cited above, the *teacher differences* on the dependent variable were ignored, i.e., the extraneous variable was not controlled.
- But in a random replications design, the effect of such differences are minimised (or reduced) by providing a number of repetitions for each treatment.
- Each repetition is technically called a ‘replication’.
- Random replication design serves two purposes viz., it provides controls for the differential effects of the extraneous independent variables and secondly, it randomizes any individual differences among those conducting the treatments.
- Diagrammatically we can illustrate the random replications design.
- From the diagram it is clear that there are two populations in the replication design.

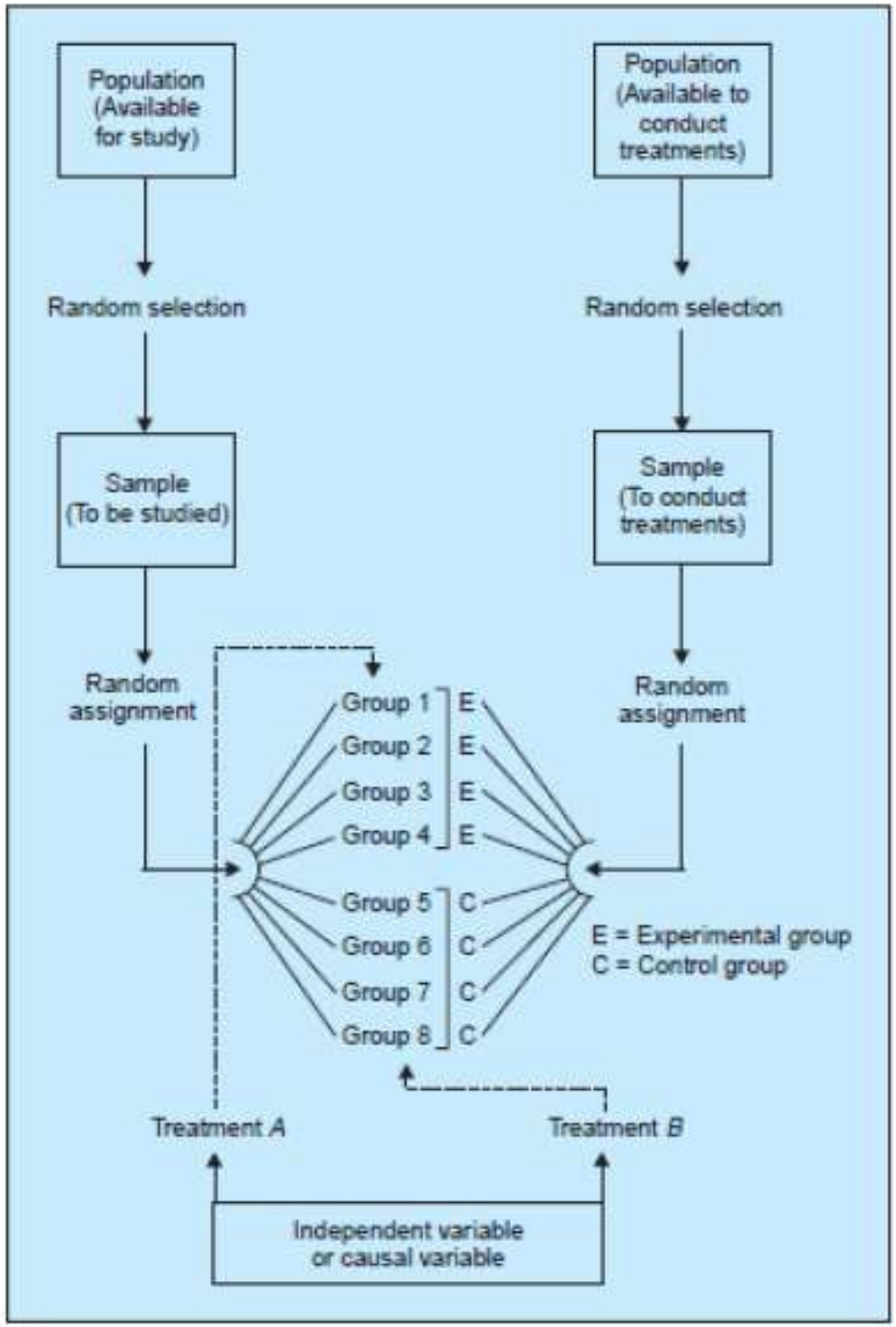


Fig. Random replication design

Important Experimental Designs

(ii) Random replications design:

- The sample is taken randomly from the population available for study and is randomly assigned to, say, four experimental and four control groups.
- Similarly, sample is taken randomly from the population available to conduct experiments (because of the eight groups eight such individuals be selected) and the eight individuals so selected should be randomly assigned to the eight groups.
- Generally, equal number of items are put in each group so that the size of the group is not likely to affect the result of the study.
- Variables relating to both population characteristics are assumed to be randomly distributed among the two groups.
- Thus, this random replication design is, in fact, an extension of the two-group simple randomized design.

Important Experimental Designs

5. Randomized block design (R.B. design)

- It is an improvement over the C.R. design.
- In the R.B. design the principle of local control can be applied along with the other two principles of experimental designs.
- In the R.B. design, subjects are first divided into groups, known as blocks, such that within each group the subjects are relatively homogeneous in respect to some selected variable.
- The variable selected for grouping the subjects is one that is believed to be related to the measures to be obtained in respect of the dependent variable.
- The number of subjects in a given block would be equal to the number of treatments and one subject in each block would be randomly assigned to each treatment.
- In general, blocks are the levels at which we hold the extraneous factor fixed, so that its contribution to the total variability of data can be measured.
- The main feature of the R.B. design is that in this each treatment appears the same number of times in each block.

Important Experimental Designs

5. Randomized block design (R.B. design)

	Very low I.Q.	Low I.Q.	Average I.Q.	High I.Q.	Very high I.Q.
	Student A	Student B	Student C	Student D	Student E
Form 1	82	67	57	71	73
Form 2	90	68	54	70	81
Form 3	86	73	51	69	84
Form 4	93	77	60	65	71

Important Experimental Designs

- The R.B. design is analysed by the two-way analysis of variance (two-way ANOVA)* technique.
- Let us illustrate the R.B. design with the help of an example.
- Suppose four different forms of a standardised test in statistics were given to each of five students (selected one from each of the five I.Q. blocks) and following are the scores which they obtained.
- If each student separately randomized the order in which he or she took the four tests (by using random numbers or some similar device), we refer to the design of this experiment as a R.B. design.
- The purpose of this randomization is to take care of such possible extraneous factors (say as fatigue) or perhaps the experience gained from repeatedly taking the test.

6. Latin square design (L.S. design):

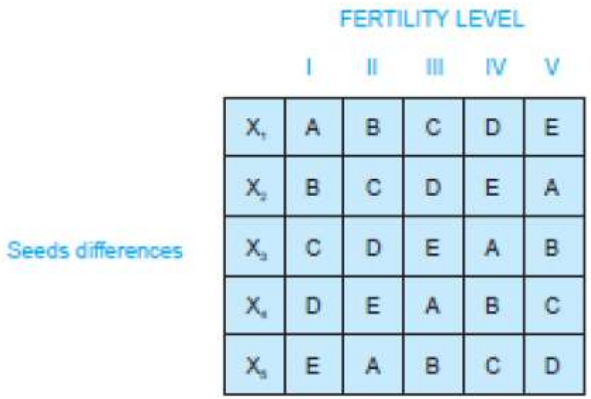
- It is an experimental design very frequently used in agricultural research. The conditions under which agricultural investigations are carried out are different from those in other studies for nature plays an important role in agriculture.
- For instance, an experiment has to be made through which the effects of five different varieties of fertilizers on the yield of a certain crop, say wheat, it to be judged.
- In such a case the varying fertility of the soil in different blocks in which the experiment has to be performed must be taken into consideration; otherwise the results obtained may not be very dependable because the output happens to be the effect not only of fertilizers, but it may also be the effect of fertility of soil.
- Similarly, there may be impact of varying seeds on the yield. To overcome such difficulties, the L.S. design is used when there are two major extraneous factors such as the varying soil fertility and varying seeds.

6. Latin square design (L.S. design):

- The Latin-square design is one wherein each fertilizer, in our example, appears five times but is used only once in each row and in each column of the design.
- In other words, the treatments in a L.S. design are so allocated among the plots that no treatment occurs more than once in any one row or any one column.
- The two blocking factors may be represented through rows and columns (one through rows and the other through columns).
- The following is a diagrammatic form of such a design in respect of, say, five types of fertilizers, viz., A, B, C, D and E and the two blocking factor viz., the varying soil fertility and the varying seeds:.

6. Latin square design (L.S. design):

- The above diagram clearly shows that in a L.S. design the field is divided into as many blocks as there are varieties of fertilizers and then each block is again divided into as many parts as there are varieties of fertilizers in such a way that each of the fertilizer variety is used in each of the block (whether columnwise or row-wise) only once.



- The analysis of the L.S. design is very similar to the two-way ANOVA technique.
- The merit of this experimental design is that it enables differences in fertility gradients in the field to be eliminated in comparison to the effects of different varieties of fertilizers on the yield of the crop.
- But this design suffers from one limitation, and it is that although each row and each column represents equally all fertilizer varieties, there may be considerable difference in the row and column means both up and across the field.

6. Latin square design (L.S. design):

- This, in other words, means that in L.S. design we must assume that there is no interaction between treatments and blocking factors.
- This defect can, however, be removed by taking the means of rows and columns equal to the field mean by adjusting the results.
- Another limitation of this design is that it requires number of rows, columns and treatments to be equal.
- This reduces the utility of this design. In case of (2 × 2) L.S. design, there are no degrees of freedom available for the mean square error and hence the design cannot be used. If treatments are 10 or more, than each row and each column will be larger in size so that rows and columns may not be homogeneous.
- This may make the application of the principle of local control ineffective. Therefore, L.S. design of orders (5 × 5) to (9 × 9) are generally used.

7. Factorial Designs

Factorial designs are used in experiments where the effects of varying more than one factor are to be

determined. They are specially important in several economic and social phenomena where usually a

large number of factors affect a particular problem. Factorial designs can be of two types: (i) simple

factorial designs and (ii) complex factorial designs. We take them separately

7. Factorial Designs

Factorial designs are used in experiments where the effects of varying more than one factor are to be

determined. They are specially important in several economic and social phenomena where usually a

large number of factors affect a particular problem. Factorial designs can be of two types: (i) simple

factorial designs and (ii) complex factorial designs. We take them separately

7. Factorial Designs

(i) Simple factorial designs:

In case of simple factorial designs, we consider the effects of varying two factors on the dependent

variable, but when an experiment is done with more than two factors, we use complex factorial designs.

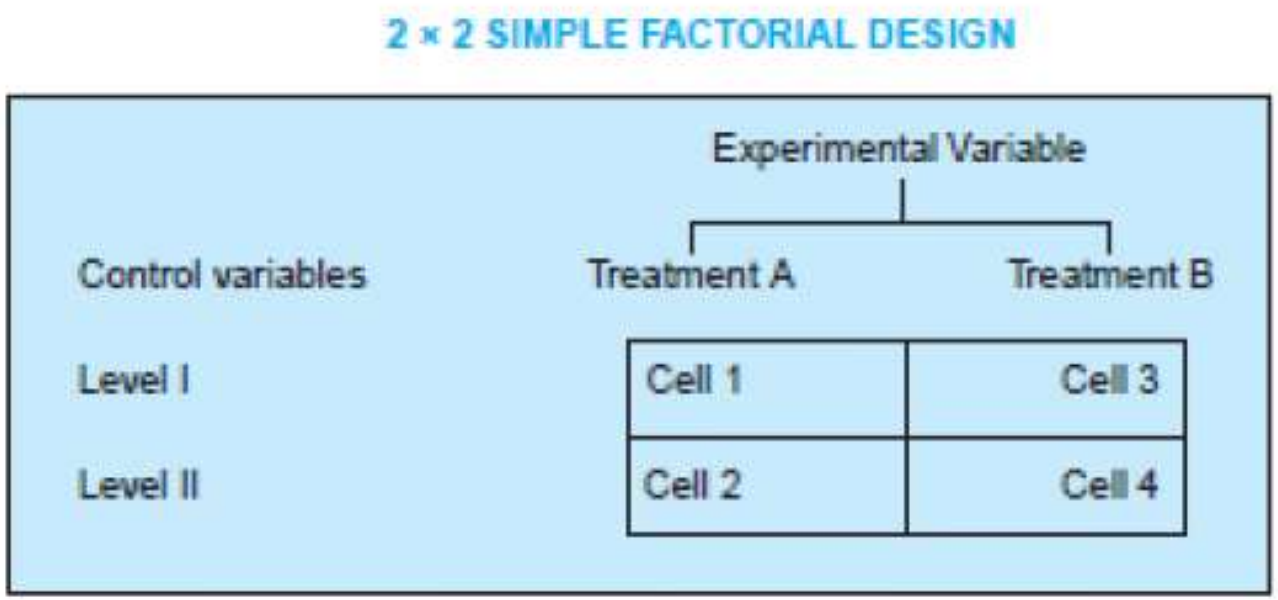
Simple factorial design is also termed as a 'two-factor-factorial design', whereas complex factorial

design is known as 'multifactor- factorial design.' Simple factorial design may either be a 2 × 2 simple

- factorial design, or it may be, say, 3 × 4 or × 3 or the like type of simple factorial design. We illustrate
- some simple factorial designs as under:

7. Factorial Designs

- **Illustration 1:** (2 × 2 simple factorial design).
- A 2 × 2 simple factorial design can graphically be depicted as follows:



7. Factorial Designs

In this design the extraneous variable to be controlled by homogeneity is called the control variable and the independent variable, which is manipulated, is called the experimental variable. Then there are two treatments of the experimental variable and two levels of the control variable. As such there are four cells into which the sample is divided. Each of the four combinations would provide one treatment or experimental condition. Subjects are assigned at random to each treatment in the same manner as in a randomized group design. The means for different cells may be obtained along with the means for different rows and columns. Means of different cells represent the mean scores for the dependent variable and the column means in the given design are termed the main effect for treatments without taking into account any differential effect that is due to the level of the control variable. Similarly, the row means in the said design are termed the main effects for levels without regard to treatment. Thus, through this design we can study the main effects of treatments as well as the main effects of levels. An additional merit of this design is that one can examine the interaction between treatments and levels, through which one may say whether the treatment and levels are independent of each other or they are not so. The following examples make clear the interaction effect between treatments and levels. The data obtained in case of two (2 × 2) simple factorial studies may be as given in Fig.

7. Factorial Designs

STUDY I DATA

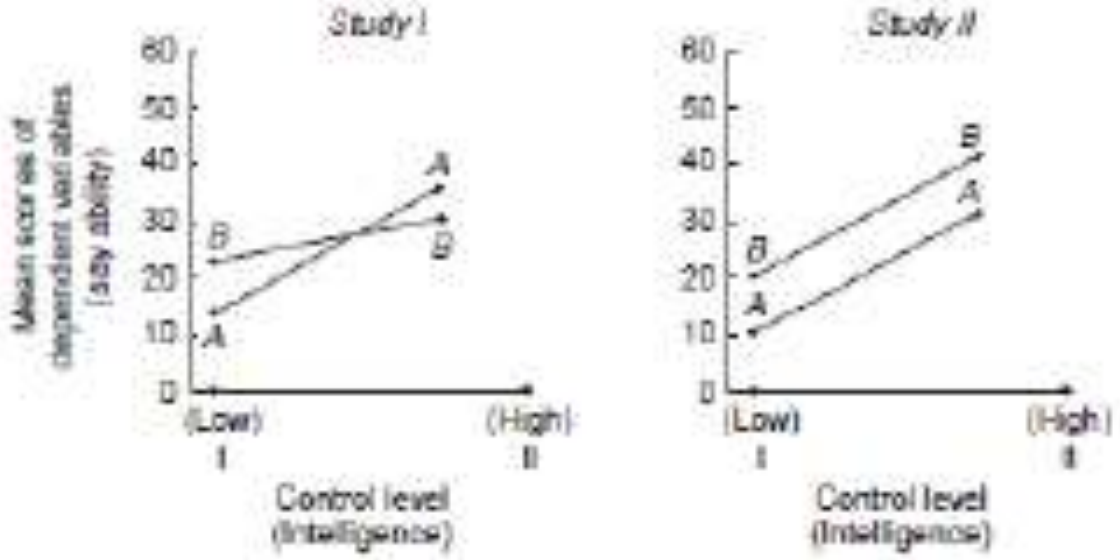
		Training		
		Treatment A	Treatment B	Row Mean
Control (Intelligence)	Level I (Low)	15.5	23.3	19.4
	Level II (High)	35.8	30.2	33.0
	Column mean	25.6	26.7	

STUDY II DATA

		Training		
		Treatment A	Treatment B	Row Mean
Control (Intelligence)	Level I (Low)	10.4	20.6	15.5
	Level II (High)	30.6	40.4	35.5
	Column mean	20.5	30.5	

7. Factorial Designs

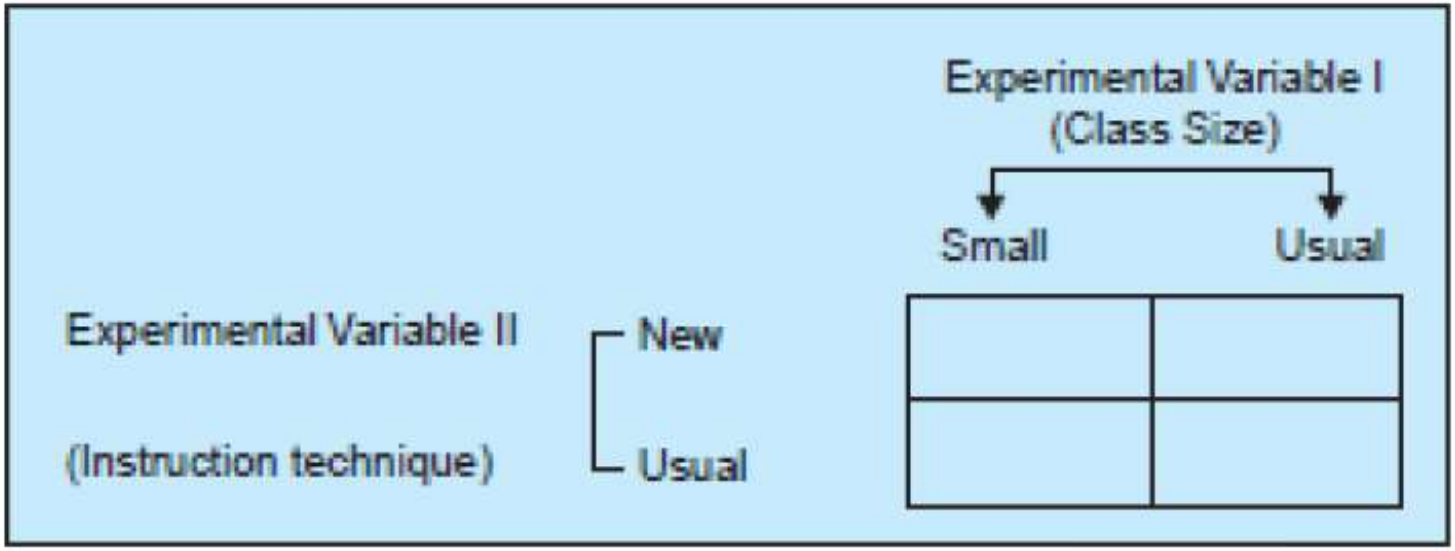
All the above figures (the study I data and the study II data) represent the respective means. Graphically, these can be represented as shown in Fig.



- The graph relating to Study I indicates that there is an interaction between the treatment and the level which, in other words, means that the treatment and the level are not independent of each other.
- The graph relating to Study II shows that there is no interaction effect which means that treatment and level in this study are relatively independent of each other.
- The 2 × 2 design need not be restricted in the manner as explained above i.e., having one experimental variable and one control variable, but it may also be of the type having two experimental variables or two control variables.

7. Factorial Designs

For example, a college teacher compared the effect of the classsize as well as the introduction of the new instruction technique on the learning of research methodology.
For this purpose he conducted a study using a 2 × 2 simple factorial design. His design in the graphic form would be as follows:



But if the teacher uses a design for comparing males and females and the senior and junior students in the college as they relate to the knowledge of research methodology, in that case we will have a 2 × 2 simple factorial design wherein both the variables are control variables as no manipulation is involved in respect of both the variables.

7. Factorial Designs

Illustration 2: (4 × 3 simple factorial design).

The 4 × 3 simple factorial design will usually include four treatments of the experimental variable and three levels of the control variable. Graphically it may take the following form:

4 × 3 SIMPLE FACTORIAL DESIGN

Control Variable	Experimental Variable			
	Treatment A	Treatment B	Treatment C	Treatment D
Level I	Cell 1	Cell 4	Cell 7	Cell 10
Level II	Cell 2	Cell 5	Cell 8	Cell 11
Level III	Cell 3	Cell 6	Cell 9	Cell 12

This model of a simple factorial design includes four treatments viz., A, B, C, and D of the experimental variable and three levels viz., I, II, and III of the control variable and has 12 different cells as shown above.

This shows that a 2 × 2 simple factorial design can be generalised to any number of treatments and levels.

Accordingly we can name it as such and such (–×–) design. In such a design the means for the columns provide the researcher with an estimate of the main effects for treatments and the means for rows provide an estimate of the main effects for the levels.

Such a design also enables the researcher to determine the interaction between treatments and levels.

7. Factorial Designs

(ii) *Complex factorial designs*:

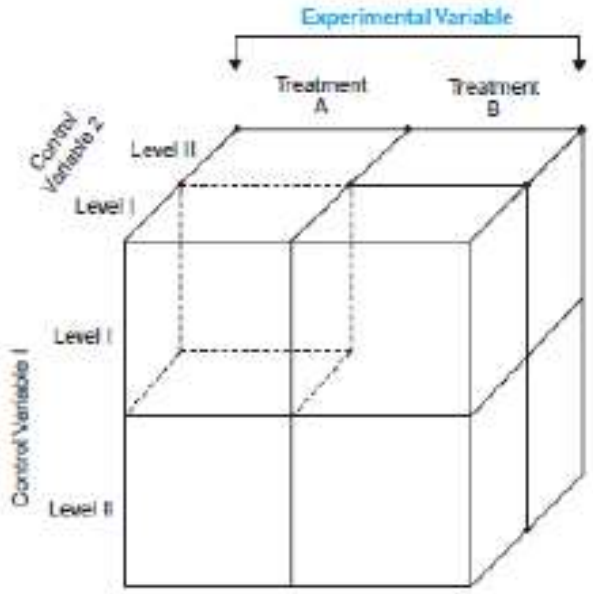
Experiments with more than two factors at a time involve the use of complex factorial designs.
A design which considers three or more independent variables simultaneously is called a complex factorial design.
In case of three factors with one experimental variable having two treatments and two control variables, each one of which having two levels, the design used will be termed 2 × 2 × 2 complex factorial design which will contain a total of eight cells as shown below in Fig.

7. Factorial Designs

2x2x2 COMPLEX FACTORIAL DESIGN

		Experimental Variable			
		Treatment A		Treatment B	
		Control Variable 2 Level I	Control Variable 2 Level II	Control Variable 2 Level I	Control Variable 2 Level II
Control Variable 1	Level I	Cell 1	Cell 3	Cell 5	Cell 7
	Level II	Cell 2	Cell 4	Cell 6	Cell 8

In Fig. a pictorial presentation is given of the design shown below.



7. Factorial Designs

The dotted line cell in the diagram corresponds to Cell 1 of the above stated 2 × 2 × 2 design and is for Treatment A, level I of the control variable 1, and level I of the control variable 2. From this design it is possible to determine the main effects for three variables i.e., one experimental and two control variables. The researcher can also determine the interactions between each possible pair of variables (such interactions are called 'First Order interactions') and interaction between variable taken in triplets (such interactions are called Second Order interactions). In case of a 2 × 2 × 2 design, the further given first order interactions are possible:

Experimental variable with control variable 1 (or EV × CV 1);
Experimental variable with control variable 2 (or EV × CV 2);
Control variable 1 with control variable 2 (or CV1 × CV2);

Three will be one second order interaction as well in the given design (it is between all the three variables i.e., EV × CV1 × CV2).

7. Factorial Designs

The dotted line cell in the diagram corresponds to Cell 1 of the above stated 2 × 2 × 2 design and is for Treatment A, level I of the control variable 1, and level I of the control variable 2. From this design it is possible to determine the main effects for three variables i.e., one experimental and two control variables. The researcher can also determine the interactions between each possible pair of variables (such interactions are called 'First Order interactions') and interaction between variable taken in triplets (such interactions are called Second Order interactions). In case of a 2 × 2 × 2 design, the further given first order interactions are possible:

Experimental variable with control variable 1 (or EV × CV 1);
Experimental variable with control variable 2 (or EV × CV 2);
Control variable 1 with control variable 2 (or CV1 × CV2);

Three will be one second order interaction as well in the given design (it is between all the three variables i.e., EV × CV1 × CV2).

7. Factorial Designs

To determine the main effects for the experimental variable, the researcher must necessarily compare the combined mean of data in cells 1, 2, 3 and 4 for Treatment A with the combined mean of data in cells 5, 6, 7 and 8 for Treatment B. In this way the main effect for experimental variable, independent of control variable 1 and variable 2, is obtained. Similarly, the main effect for control variable 1, independent of experimental variable and control variable 2, is obtained if we compare the combined mean of data in cells 1, 3, 5 and 7 with the combined mean of data in cells 2, 4, 6 and 8 of our 2 × 2 × 2 factorial design. On similar lines, one can determine the main effect for the control variable 2 independent of experimental variable and control variable 1, if the combined mean of data in cells 1, 2, 5 and 6 are compared with the combined mean of data in cells 3, 4, 7 and 8. To obtain the first order interaction, say, for EV × CV1 in the above stated design, the researcher must necessarily ignore control variable 2 for which purpose he may develop 2 × 2 design from the 2 × 2 × 2 design by combining the data of the relevant cells of the latter design as shown in Fig.

		Experimental Variables	
		Treatment A	Treatment B
Control Variable 1	Level I	Cells 1, 3	Cells 5, 7
	Level II	Cells 2, 4	Cells 6, 8

7. Factorial Designs

Similarly, the researcher can determine other first order interactions. The analysis of the first order interaction, in the manner described above, is essentially a sample factorial analysis as only two variables are considered at a time and the remaining one is ignored. But the analysis of the second order interaction would not ignore one of the three independent variables in case of a 2 × 2 × 2 design. The analysis would be termed as a complex factorial analysis. It may, however, be remembered that the complex factorial design need not necessarily be of 2 × 2 × 2 type design, but can be generalised to any number and combination of experimental and control independent variables. Of course, the greater the number of independent variables included in a complex factorial design, the higher the order of the interaction analysis possible. But the overall task goes on becoming more and more complicated with the inclusion of more and more independent variables in our design.

7. Factorial Designs

Factorial designs are used mainly because of the two advantages.

(i) They provide equivalent accuracy (as happens in the case of experiments with only one factor) with less labour and as such are a source of economy. Using factorial designs, we can determine the main effects of two (in simple factorial design) or more (in case of complex factorial design) factors (or variables) in one single experiment.

(ii) They permit various other comparisons of interest. For example, they give information about such effects which cannot be obtained by treating one single factor at a time. The determination of interaction effects is possible in case of factorial designs.